Feed Utilization by Cattle

Effects of NPN Content of Alfalfa and Red Clover Silages on the Production of Lactating Cows
J. J. Olmos Colmenero, A. F. Brito, G. A. Broderick, S. M. Reyal

Introduction

There is evidence that reducing the NPN content of hay-crop silages will improve protein efficiency in lactating dairy cows. Previous research showed that formic acid treatment of alfalfa silage (AS) reduced NPN and improved milk production (Nagel and Broderick, J. Dairy Sci. 75:140-154, 1992; Broderick and Radloff, 2002 USDFRC Res. Sum.). The lower NPN content of red clover silage (RCS) also has been shown to be related to improved protein efficiency when it replaces AS in the diet (Broderick, 2001 USDFRC Res. Sum.). This study was conducted to compare feeding all of the dietary forage as control AS, AS treated with ammonium tetraformate (ATF; GrasAAT®,HydroAgri, Norway), or as RCS of either early or late maturity. The effect of these forages on milk production and ruminal metabolites was assessed in lactating dairy cows.

Materials and Methods

Alfalfa silage was harvested from third cutting and two RCS were harvested as early or late maturity from second cutting. The late RCS (RCS1) was harvested at about the same maturity as was used in earlier feeding studies; the early RCS (RCS2) was harvested to obtain a forage about equal in CP to the AS. All forages were cut using a conventional mower conditioner, field-wilted to about 40% DM and then chopped at harvest to a theoretical length of 2.9 cm. Control AS and both RCS were ensiled without additives; the formate-treated AS (FAS) was treated with 6.2 L ATF/ton of wet forage while being chopped. Three forages were ensiled in upright concrete stave silos and RCS2 was ensiled in a bag silo. No forage was rained on during harvest. Both AS and RCS1 also were fed in another study (Broderick and Radloff, 2002 USDFRC Res. Sum.). Forage compositions are in Table 1. Twenty-four Holstein cows (eight with ruminal cannulae) averaging 192 DIM were blocked by parity and DIM into six squares of four; cows within squares were randomly assigned to balanced diet sequences in a 4x4 Latin square trial. The TMR were formulated to contain 50% of total DM from one of the four silages. Diet compositions are in Table 2. Experimental periods were 4-wk long (total 16 wk); production data were collected during the last 2-wk of each period. At the end of each period, ruminal samples were collected over the 24-h clock from the eight cannulated cows and spot urine and fecal samples were collected from all cows. Urine volume was estimated from creatinine; apparent nutrient digestibility was estimated using indigestible ADF as internal marker. Statistical analysis was done using proc mixed in SAS; differences between least square means were reported only if the F-test for treatment was significant ($\alpha \le 0.05$).

Results and Discussion

The silages differed in composition (Table 1). As expected, RCS1 was lower in CP than, and RCS2 more similar to, the two AS. The NDF content of RCS1 was higher than the other three silages. That the two AS and RCS1 were equal, but RCS2 lower, in ADF translated into higher hemicellulose levels in both RCS. These differences between RCS and AS have been found in most previous studies comparing AS and RCS. The two RCS contained only 56% as much NPN as control AS. Treatment with ATF tended to depress silage pH and added 1.2 percentage units of extra CP from the ammonia N in this compound. Despite the added NPN, FAS had nearly 10% less NPN than control AS, even when expressed as a proportion of total N. Most of the reduction in NPN was due to lower free AA N. Both RCS (particularly RCS1) had high levels of ADIN. In previous trials, RCS averaged (% of total N) 5.1% ADIN versus 3.5% ADIN in AS. High levels of ADIN may depress protein utilization. Elevated ADIN indicated that both of the RCS fed in this trial were not typical and may have over-heated in the silo.

Diets containing AS and FAS had similar compositions; however, the two RCS diets, despite weekly adjustment of soybean meal to equalize N contents, contained about 1 and 2 percentage units less CP (Table 2). Production and nutrient utilization data are summarized in Table 3. Intake of DM was greater on the diet with FAS, intermediate on control AS and RCS1, and lowest on RCS2 (the higher quality RCS). Despite the differences in DMI, weight gain was greater on RCS. Previously, we have observed lower DMI and somewhat greater weight gain when RCS replaced AS in the diet. Milk and SNF yields paralleled DMI. Yield of FCM, fat, and protein all were greater on the two AS versus the two RCS. Although apparent N efficiency was higher and concentrations of milk and blood urea lower on the two RCS, these effects were confounded by the lower N contents of both diets. Other than a reduction in the proportion of milk NPN present as urea, there were no significant effects on production due to formate-treatment of AS in this trial. In our other work feeding the same two silages, we found improved intake and milk yield when FAS replaced control AS (Broderick and Radloff, 2002 USDFRC Res. Sum.). However, mean DMI was nearly 2 kg/d greater in that study. Nutrient digestibility and urinary N excretion were about equal on the two AS diets. However, digestibility of DM, organic matter, NDF, ADF, and hemicellulose all were highest on RCS2 and intermediate on RCS1, reflecting its later maturity. Differences similar to those found between the RCS1 diet and the two AS diets have been observed in all of previous trials comparing these forages where digestibility measurements were made. It is possible that the NEL derived from greater nutrient digestibility (especially on RCS2) were not reflected in improved production because the energy was deposited in body tissue. The lower N digestibilities on RCS probably reflected both the lower CP contents of those diets (Table 2) as well as the high proportions of ADIN (Table 1). Feeding RCS reduced urinary N excretion. It appeared that N utilization was impaired by elevated ADIN levels in the RCS fed in this trial.

Mean metabolite concentrations observed in the rumen when these diets were fed are in Table 4. Ruminal pH, total VFA, and molar proportions of the principal VFA were not altered by diet. Also, no differences resulted from feeding control AS or FAS. Ruminal concentrations of protein degradation products are, of course, influenced by dietary protein intake; however, feeding the two RCS diets reduced ammonia by nearly 50%. Moreover, branched-chain VFA, which are formed from catabolism of branched-chain AA released from protein degradation in the rumen, also were substantially reduced versus feeding the AS diets. Ruminal free AA, which derive partly from dietary protein degradation, were highest on control AS and lowest on RCS1. It was interesting that free AA concentrations were not different between FAS and RCS2. Overall, the pattern of ruminal metabolites indicated that protein degradation was lower on the RCS versus AS in this trial.

Summary and Conclusion

Treating AS with ATF reduced NPN content but its feeding did not result in increased intake or milk yield. Average and high quality RCS both had only 56% as much NPN as control AS; however, both also had elevated ADIN compared to previous trials. Feeding diets containing these RCS increased digestibility of DM and fiber and weight gain but reduced intake and milk production. The RCS diets were lower in CP and gave small increases in N efficiency and reductions in urinary N excretion. Ruminal metabolite patterns also indicated that protein degradation was reduced. The results of this experiment showed no production advantages in lactating dairy cows to formic acid treatment of AS or to feeding of RCS.

Table 1. Composition of alfalfa, formate-treated alfalfa, and red clover silages.[1]

	Silage					
Item	AS	FAS	RCS1	RCS2	SE	*P* > F
DM, %	41.8	42.2	43.4	41.8	0.7	0.85
CP, % of DM	24.8^{b}	26.0^{a}	18.9^{d}	23.5^{c}	0.3	< 0.01
Ash, % of DM	11.1^{c}	10.9^{c}	12.3^{b}	12.7^{a}	0.1	< 0.01
NDF, % of DM	39.4^{b}	39.0^{b}	41.4^{a}	40.0^{b}	0.4	0.04
ADF, % of DM	31.1^{a}	30.3^{a}	31.2^{a}	28.1^{b}	0.4	< 0.01
Hemicellulose, % of DM	8.3^{c}	8.7^{c}	10.2^{b}	11.9^{a}	0.2	< 0.01
pH	4.96	4.70	4.86	4.94	0.08	0.07
NPN, % of total N	50.0^{a}	45.4^{b}	27.2^{c}	29.0^{c}	0.9	< 0.01
NH_3-N, % of total N	4.1^{a}	3.4^{b}	2.6^{c}	3.5^{b}	0.1	< 0.01
Free AA-N, % of total N	39.3^{a}	30.1^{b}	12.6^{d}	17.0^{c}	0.6	< 0.01
ADIN, % of total N	4.2^{c}	4.0^{c}	16.8^{a}	9.9^{b}	0.6	< 0.01

[a,b,c,d]Means in the same row with different superscripts differ ($P < 0.05$).

[1]AS = Alfalfa silage, FAS = ammonium tetraformate treated alfalfa silage, RCS1 and RCS2 = red clover silages no. 1 and no. 2, SE = standard error.

[2]Probability of an effect of silage source.

Table 2. Composition of diets.[1]

Item	Diet[1] AS	FAS	RCS1	RCS2
	% of DM			
Alfalfa silage	50.0	. . .	. . .	. . .
Formate-treated alfalfa silage	. . .	50.0	. . .	. . .
Red clover silage #1	. . .	. . .	50.0	. . .
Red clover silage #2	. . .	. . .	. . .	50.0
Rolled corn silage	10.0	10.0	10.0	10.0
High moisture shelled corn	37.8	37.3	29.3	36.6
Solvent soybean meal	1.8	2.3	10.3	3.0
Salt	0.3	0.3	0.3	0.3
Vitamin-mineral premix[2]	0.1	0.1	0.1	0.1
Chemical composition				
Crude protein	18.9	19.0	16.9	17.9
NDF	32.2	32.0	34.2	33.3
ADF	22.3	22.0	22.2	20.9

[1]AS = alfalfa silage, FAS = ammonium-tetraformate treated alfalfa silage, RCS = red clover silage, CS = corn silage.

[2]Provided (/kg DM) 56 mg of Zn, 46 mg of Mn, 22 mg of Fe, 12 mg of Cu, 0.9 mg of I, 0.4 mg of Co, 0.3 mg of Se, 6440 IU of vitamin A, 2000 IU of vitamin D, and 16 IU of vitamin E.

Table 3. Effect of feeding forage as control alfalfa silage (AS) or formate-treated alfalfa silage (FAS), or as one of two red clover silages (RCS1 and RCS2), on production of lactating cows.

Item	Diet AS	FAS	RCS1	RCS2	SE	$P > F$[1]
DM intake, kg/d	23.3[ab]	23.7[a]	22.2[bc]	21.5[c]	0.7	0.01
BW gain, kg/d	0.19[bc]	0.09[c]	0.66[a]	0.62[ab]	0.25	0.03
Milk, kg/d	30.5[a]	30.8[a]	29.5[ab]	28.6[b]	0.8	0.03
3.5% FCM, kg/d	33.4[a]	33.6[a]	31.4[b]	30.5[b]	1.0	<0.01
Milk/DMI	1.33	1.31	1.34	1.34	0.03	0.73
Milk N/N intake, %	22.3[b]	22.4[b]	24.6[a]	23.2[ab]	<0.01	<0.01
Fat %	4.00	4.01	3.88	3.84	0.12	0.32
Fat, kg/d	1.23[a]	1.25[a]	1.14[b]	1.10[b]	0.04	<0.01
Protein, %	3.24[b]	3.31[a]	3.19[bc]	3.16[c]	0.04	<0.01
Protein, kg/d	0.99[a]	1.02[a]	0.94[b]	0.90[b]	0.03	<0.01
Lactose, %	4.81	4.81	4.84	4.80	0.05	0.87
Lactose, kg/d	1.50	1.49	1.44	1.39	0.04	0.06
SNF, %	8.97	9.04	8.93	8.86	0.07	0.12
SNF, kg/d	2.78[a]	2.79[a]	2.65[ab]	2.56[b]	0.08	0.01
Milk NPN, mg/dl	31.3	33.3	32.6	31.7	1.3	0.32
MUN,[2] mg/dl	19.1[a]	18.1[a]	15.3[b]	14.9[b]	0.8	<0.01
MUN/milk NPN	62.4[a]	55.0[b]	47.3[c]	48.3[c]	<0.1	<0.01
Blood urea N, mg/dl	11.6[a]	11.7[a]	9.8[b]	10.1[b]	0.3	<0.01
Apparent Digestibility, %						
DM	58.7[c]	57.4[c]	60.7[b]	63.9[a]	1.1	<0.01
Organic matter	59.2[bc]	57.6[c]	60.6[b]	64.1[a]	1.1	<0.01
NDF	37.2[c]	36.9[c]	48.2[b]	55.0[a]	1.2	<0.01
ADF	40.2[c]	40.1[c]	50.7[b]	57.3[a]	1.1	<0.01
Hemicellulose	30.2[c]	29.8[c]	43.8[b]	50.9[a]	1.7	<0.01
N	55.9[a]	55.9[a]	45.5[c]	50.8[b]	1.2	<0.01
Excretion, g/d						
Urinary N	209.5[a]	210.9[a]	151.3[b]	158.0[b]	5.8	<0.01

[a,b,c]LS Means in the same row with different superscripts differ ($P < 0.05$).
[1]Probability of a significant effect of diet.
[2]MUN = Milk urea N.

Table 4. Effect of feeding forage as control alfalfa silage (AS) or formate-treated alfalfa silage (FAS), or as one of two red clover silages (RCS1 and RCS2), on ruminal metabolites.

	Diet					
Item	AS	FAS	RCS1	RCS2	SE	$P > F$[1]
pH	6.38	6.41	6.45	6.45	0.05	0.32
NH_3, mg/dl	14.0[a]	12.7[a]	6.5[b]	7.9[b]	1.0	< 0.01
Free AA, mM	3.97[a]	3.44[ab]	2.29[c]	2.85[bc]	0.40	< 0.01
Total VFA, mM	118.2	117.6	117.7	114.6	4.3	0.70
Molar proportions, mol/100 mol						
Acetate	62.9	62.7	64.4	64.1	2.0	0.73
Propionate	18.0	18.0	18.6	18.5	0.8	0.77
Acetate: Propionate	3.56	3.57	3.55	3.54	0.09	0.99
Butyrate	11.1	11.5	10.8	10.7	0.5	0.20
Isobutyrate	1.32[a]	1.23[a]	0.84[b]	0.93[b]	0.05	< 0.01
Isovalerate + 2-methylbutyrate	2.08[a]	1.92[a]	0.97[c]	1.21[b]	0.10	< 0.01
Valerate	1.65	1.61	1.41	1.49	0.13	0.13

[a,b,c]LS Means in the same row with different superscripts differ ($P < 0.05$).
[1]Probability of a significant effect of diet.

Alfalfa Silage Versus Formate-Treated Alfalfa Silage or Red Clover Silage for Lactating Dairy Cows

G.A. Broderick and W.J. Radloff

Introduction

The large amounts of NPN in alfalfa silage (AS) reduce protein efficiency when fed to lactating dairy cows. Red clover silage (RCS) typically has 30 to 40% less NPN, as a proportion of total N, than AS. Research conducted at the Dairy Forage Center found that the enzyme polyphenol oxidase acts in RCS to reduce NPN formation (Jones et al., J. Sci. Food Agric. 67:329-333, 1995) and has shown that protein efficiency is improved when RCS replaces AS (Broderick, 2001 USDFRC Res. Sum.). Although DM efficiency (milk/DMI) has been consistently greater on RCS than AS, depressed DMI on RCS reduced total milk yield in two out of five trials. Formic acid treatments are used extensively in Europe to reduce NPN formation in grass silage. This feeding study was conducted to test the effectiveness of feeding dairy cows forage as control AS or AS treated with ammonium tetraformate (ATF; GrasAAT®, HydroAgri, Norway), or as RCS supplemented with dried molasses to counteract the depressed DMI that occurs with that forage.

Materials and Methods

Alfalfa silage was harvested from third cutting and RCS was harvested from second cutting. Forages were cut using a conventional mower conditioner and field-wilted to about 40% DM. All forages were chopped to a theoretical length of 2.9 cm. Control AS and RCS were ensiled without additives; formate-treated AS (FAS) was treated with 6.2 L ATF/ton of wet forage while being chopped. Forages were ensiled in three upright concrete stave silos and no forage was rained on during harvest. Silage compositions are in Table 1. Fifteen Holstein cows averaging 256 DIM were blocked by parity and DIM into five squares of three; cows within squares were randomly assigned to diet sequences in a 3x3 Latin square trial. The TMR were formulated to contain (DM basis) 40% AS or FAS plus 20% corn silage, or 54% RCS plus 6% dried molasses. Diet compositions are in Table 2. Experimental periods were 4-wk long (total 12-wk); production data were collected during the last 2-wk of each period. Spot fecal samples were collected at the end of each period and apparent nutrient digestibility was estimated using indigestible ADF as internal marker. Statistical analysis was done using proc mixed in SAS; differences between least square means were reported only if the F-test for treatment was significant (≤ 0.05).

Results and Discussion

The silages differed in a number of composition characteristics (Table 1). As expected, RCS was lower in CP than AS. The 24% CP in control AS probably occurred because it was from third cutting. The RCS was slightly higher in NDF but similar in ADF; this translated into 1.5 to 2 percentage units more hemicellulose in RCS than AS. The RCS was much lower in NPN than the AS, with only 56% of that in control AS. Treatment with ATF depressed silage pH but also added ammonia N; the 1.3 percentage units of extra CP in FAS derived from this NPN. Despite the added NPN from ATF, FAS had about 10% less NPN, even when expressed as a proportion of total N. Most of the reduction in NPN was related to reduced levels of free AA. A surprising finding was that ADIN in RCS that was four times that in AS and FAS. In five previous trials, RCS averaged (% of total N) 5.1% ADIN versus 3.5% ADIN in AS. High levels of ADIN will depress protein utilization.

Elevated ADIN indicated that the RCS fed in this trial was not typical and may have over-heated in the silo.

Diets containing AS and FAS had similar compositions; however, the RCS diet contained 1.7 percentage units less CP (Table 2) because it was anticipated that control AS would contain only 21% CP. Production and nutrient utilization results are summarized in Table 3. Intake of DM was greater on the RCS diet versus control AS, indicating that adding dried molasses had the desired effect of countering the depressed feed consumption previously seen with RCS. Although apparent N efficiency was higher and milk urea lower on RCS, the greater intake did not result in improved milk production versus that on the control AS diet. Feeding FAS increased DMI as well as yields of milk, FCM, protein, lactose, and SNF compared to the other two diets. Nutrient digestibility and excretion were similar on the two AS diets. However, digestibility of DM, Organic matter, NDF, ADF, and hemicellulose all were higher on RCS. Improvements of this magnitude were observed in all of the previous trials comparing AS and RCS where digestibility measurements were made. Greater nutrient digestibility was reflected in the lower fecal DM excretion on RCS. Apparent N digestibility was 17% lower on RCS. Although the importance of this depression is confounded by the lower CP content of that diet (Table 2), a difference of this magnitude probably reflected the high proportion of ADIN in RCS (Table 1). Average N efficiency was increased from 23.6% on AS to 27.1% on RCS in five previous trials (Broderick, 2001 USDFRC Res. Sum.). The improvement of only 1-percentage unit versus control AS, and the greater fecal N excretion, suggested that N utilization was impaired by the elevated ADIN in the RCS fed in this trial. Versus both AS, feeding RCS diverted N excretion from urine to feces. Greater nutrient digestibilities and lower NPN content suggested that feeding RCS would result in improved nutrient efficiencies and lower environmental N losses than feeding AS.

The NEL requirements for maintenance, BW gain, and milk output (based on observed fat and SNF content) were used to estimate relative energy contents of the forages (Table 4). The NEL requirements for mean production were higher on FAS and RCS (average 34.8 Mcal/d) versus AS (33.1 Mcal/d). Subtracting the NEL computed to come from the concentrate portion of the diet yielded estimates of NEL supplied by AS and RCS. Per unit DM, the two AS were computed to have 0.73 Mcal/kg, versus 0.89 Mcal/kg for RCS. The absolute values of these estimates are probably low; however, they indicate that RCS contained 20% more NEL than AS, despite the AS having 2 percentage units less NDF (Table 1). Much of the difference in productive energy among the diets was due to greater NEL deposited for weight gain on RCS. Previously, we have observed that cows fed RCS gain more weight, and have a tendency for reduced milk fat content, versus feeding the same amounts of DM from AS.

Summary and Conclusion

Treating AS with ATF reduced NPN content and, when fed with some corn silage, increased intake and milk yield compared to untreated AS. Feeding a diet with all the forage from RCS, but with dried molasses added to stimulate intake, increased DMI but did not alter production. The RCS diet was lower in CP but did not give N efficiency greater than the FAS diet. The RCS fed in this trial was usually high in ADIN, which appeared to have impaired N utilization. Although total N excretion was similar among the three diets, feeding RCS diverted N from urine to feces. The estimated NEL content of RCS was more than 20% greater than that in AS and FAS. The results of this experiment suggested that formic acid treatment of AS lowered silage NPN and improved milk production in lactating dairy cows. However, high levels of ADIN may have impaired production on RCS in this trial.

Table 1. Composition of alfalfa, formate-treated alfalfa, and red clover silages.[1]

	Forage				
Item	AS	FAS	RCS	SE	$P > F$[2]
DM, %	39.8	40.2	42.9	0.7	0.36
CP, % of DM	24.4[b]	25.7[a]	18.1[c]	0.2	< 0.01
Ash, % of DM	11.1[b]	11.0[b]	12.3[a]	0.1	< 0.01
NDF, % of DM	39.6[b]	38.9[b]	41.3[a]	0.4	0.05
ADF, % of DM	31.4	30.3	31.1	0.4	0.29
Hemicellulose, % of DM	8.2[b]	8.7[b]	10.1[a]	0.2	< 0.01
pH	4.97[a]	4.68[b]	4.80[ab]	0.07	< 0.01
NPN, % of total N	49.4[a]	44.7[b]	27.5[c]	1.0	< 0.01
NH_3-N, % of total N	4.2[a]	3.5[b]	2.6[c]	0.14	< 0.01
Free AA-N, % of total N	39.6[a]	30.0[b]	12.7[c]	0.66	< 0.01
ADIN, % of total N	4.2[b]	3.9[b]	16.6[a]	0.6	< 0.01

[a,b,c]LS Means in the same row with different superscripts differ ($P < 0.05$).

[1]AS = Alfalfa silage, FAS = ammonium tetraformate treated alfalfa silage, RCS = red clover silage, SE = standard error.

Table 2. Composition of diets.

	Diet[1]		
Item	AS	FAS	RCS
	% of DM		
Alfalfa silage	40.4	. . .	. . .
Formate-treated alfalfa silage	. . .	40.1	. . .
Red clover silage	. . .	. . .	54.0
Rolled corn silage	20.0	20.1	. . .
Dried molasses	. . .	. . .	5.9
High moisture shelled corn	32.9	33.1	33.4
Solvent soybean meal	6.3	6.3	6.3
Salt	0.3	0.3	0.3
Vitamin-mineral premix[2]	0.1	0.1	0.1
Chemical composition			
Crude protein	18.0	18.0	16.3
Organic matter	92.2	92.2	90.0
NDF	33	33	33
ADF	23	22	22
Total sugars	2.4	2.5	4.6
Non-fiber carbohydrate	39	40	38

[1]AS = Alfalfa silage, FAS = ammonium-tetraformate treated alfalfa silage, RCS = red clover silage.

[2]Provided (/kg DM) 56 mg of Zn, 46 mg of Mn, 22 mg of Fe, 12 mg of Cu, 0.9 mg of I, 0.4 mg of Co, 0.3 mg of Se, 6440 IU of vitamin A, 2000 IU of vitamin D, and 16 IU of vitamin E.

Table 3. Effect of feeding control alfalfa silage (AS) or formate-treated alfalfa silage (TAS) plus corn silage, or red clover silage (RCS) plus molasses, on production of lactating cows.

Item	Diet AS	Diet FAS	Diet RCS	SE	$P > F$[1]
DM intake, kg/d	24.0[b]	25.0[a]	24.9[a]	0.8	< 0.01
BW gain, kg/d	0.31	0.44	0.64	0.16	0.37
Milk, kg/d	27.8[b]	30.2[a]	28.4[b]	1.0	0.01
3.5% FCM, kg/d	30.3[b]	32.4[a]	30.0[b]	1.2	0.04
Milk/DMI	1.16[ab]	1.20[a]	1.15[b]	0.03	0.05
Milk N/N intake, %	21.1b	22.4[a]	22.3[a]	0.4	0.01
Fat, %	4.20[a]	3.96[b]	3.95[b]	0.15	< 0.01
Fat, kg/d	1.14	1.19	1.10	0.06	0.08
Protein, %	3.40[a]	3.43[a]	3.29[b]	0.08	< 0.01
Protein, kg/d	0.93[b]	1.03[a]	0.92[b]	0.04	< 0.01
Lactose, %	4.74	4.78	4.79	0.06	0.21
Lactose, kg/d	1.30[b]	1.44[a]	1.34[b]	0.06	0.01
SNF, %	9.05[ab]	9.12[a]	8.99[b]	0.12	0.02
SNF, kg/d	2.48[b]	2.75[a]	2.52[b]	0.10	< 0.01
Milk urea, mg/dl	17.8[a]	18.0[a]	13.8[b]	0.4	< 0.01
Apparent Digestibility, %					
DM	57.0[b]	56.6[b]	63.3[a]	1.2	< 0.01
Organic matter	58.1[b]	57.4[b]	63.5[a]	1.3	< 0.01
NDF	35.5[b]	35.6[b]	53.2[a]	1.1	< 0.01
ADF	40.6[b]	38.0[b]	55.2[a]	1.7	< 0.01
Hemicellulose	24.3[b]	30.7[b]	49.0[a]	3.6	< 0.01
N	55.8[a]	55.3[a]	46.0[b]	1.4	< 0.01
Excretion, kg/d					
Fecal DM	10.4[a]	10.9[a]	9.1[b]	0.5	< 0.01
Fecal N	0.298[b]	0.318[b]	0.351[a]	0.015	0.01
Urinary N (difference)[2]	0.232[a]	0.231[a]	0.156[b]	0.011	< 0.01

[a,b]LS Means in the same row with different superscripts differ ($P < 0.05$).

[1]Probability of a significant effect of diet.

[2]Urinary N = N Intake - Milk N - Fecal N.

Table 4. Estimated NE_L contents of control alfalfa silage (AS), formate-treated alfalfa silage (FAS) and red clover silage (RCS).

Item	AS	FAS	RCS
Total DMI, kg/d	24.0	25.0	24.9
NE_L requirement[1]			
Maintenance (668 kg), Mcal/d	10.5	10.5	10.5
BW gain, Mcal/d	1.6	2.3	3.3
Milk yield, Mcal/d	21.0	22.1	20.8
Total requirement, Mcal/d	33.1	34.9	34.6
Non-HCS[2] DMI, kg/d	14.3	15.0	11.5
Non-HCS NE_L,[3] Mcal/kg	1.83	1.83	1.98
Non-HCS NE_L, Mcal/d	26.1	27.4	22.6
Hay-crop silage NE_L, Mcal/d	7.0	7.4	11.9
Hay-crop silage DMI, kg/d	9.7	10.0	13.4
Hay-crop silage NE_L, Mcal/kg	0.72	0.74	0.89
Relative NE_L, %	100	103	124

[1]Computed based on NRC Nutrient Requirements of Dairy Cattle, 7th Revised Edition (2001):

NE_L (Mcal/d) for maintenance = 0.08 x $BW^{0.75}$

NE_L (Mcal/d) for gain = 5.12 x BW gain

NE_L (Mcal/d) for milk = Milk x (0.0962 x % fat + 0.3512)

[2]Non-HCS = non hay-crop silage ingredients.

[3]Mean NE_L contents of DM from Non-HCS at 3X maintenance computed from NRC (2001) tables.

Effect of Level of Rumen Degradable Protein on Milk Yield and N Utilization in Lactating Dairy Cows

S. M. Reynal, G. A. Broderick

Introduction

Feeding ruminal degraded protein (RDP) in excess of the requirement for maximal microbial protein formation is wasted because the extra RDP will be converted to urea N and largely excreted in the urine. Urinary urea is the most labile form of excretory N; it can be rapidly hydrolyzed to ammonia which may volatilized before it has a chance to be incorporated into growing crops. Urinary N may also contribute to pollution of surface and ground water. On the other hand, feeding RDP levels below requirement can compromise microbial protein production, ruminal digestion, and energy and protein availability to the cow. Our objective was to determine the optimum concentration of RDP level in diets fed to lactating dairy cows.

Materials and Methods

Twenty-eight Holstein cows (eight with ruminal cannulas) averaging 192 DIM were blocked by parity and DIM into seven squares of four; cows within squares were randomly assigned to balanced diet sequences in a 4x4 Latin square trial. Four TMR were formulated to contain 50% of dietary DM from forage (three-fourths from corn silage and one-fourth from second cutting alfalfa silage) and 50% from four different concentrate mixes. Concentrations of dietary RDP were varied incrementally from 13.7% to 7.5% of DM by step-wise deletion of urea and replacement of solvent soybean meal with SoyPass¨ (LignoTech, Rothchild, WI), a rumen-protected soybean meal. Diet compositions are in Table 1. Experimental periods were 4-wk long (total 16 wk); production data were collected during the last 2-wk of each period. At the end of each period, ruminal samples were collected over the 24-h clock from the eight cannulated cows and spot urine and fecal samples were collected from all cows. Urinary excretion was estimated from creatinine; apparent nutrient digestibility was estimated using indigestible ADF as internal marker. Statistical analysis was done using proc mixed in SAS; differences between least square means were reported only if the F-test for treatment was significant ($\alpha \leq 0.05$).

Results and Discussion

Dietary CP was not constant because of the stepwise deletion of urea that was not replaced by other sources of N (Table 1). This was necessary to obtain diets that varied from being substantially in excess, to being well below, the NRC (2001) RDP requirement. However, there was little difference over the four diets in NDF, ADF, and computed NE$_L$ contents. Thus, the major differences across diets was the decreasing content and rumen balance for RDP, and the increasing content and rumen balance for rumen undegraded protein (RUP) (Table 1). There were no effects on DMI, weight gain, yield of milk and FCM, milk fat and lactose content and yield, or milk SNF content over the ranges of RDP and RUP fed in this trial (Table 2). However, the significant effects of dietary RDP concentration were restricted to milk protein and SNF: there were linear effects on protein content and yield and quadratic effects on protein and SNF yield. As expected, there were linear effects of dietary RDP on both milk and blood urea, with concentrations at the two higher levels being greater than those at the two lower levels. An interesting finding was the quantitative difference between milk urea determined by infrared analysis (AgSource, Verona, WI) and by colorimetric assay. The pattern of statistical differences was the same for both data sets, but milk urea N determined by colorimetry averaged 2.6 mg/dl greater than milk urea N assayed using infrared analysis.

There were linear declines in urinary volume and urinary excretion of total N and allantoin with decreasing dietary RDP content (Table 2). Based on the similar milk protein yields from 13.7 through 9.5% dietary RDP, urinary total N excretion could be decreased from 288 to 255 g/d without affecting protein production. Urinary allantoin derives from liver purine catabolism and, because absorbed purines originate largely from microbial cells from the rumen, allantoin excretion represents an indirect estimate of ruminal protein synthesis. Yield of microbial nonammonia N (NAN) was estimated by computing ruminal purine flow from urinary allantoin excretion (Vagnoni et al., J. Dairy Sci. 80:1695-1702, 1997) and computing microbial NAN from purine flow (Reynal et al., J. Dairy Sci. 86:1292-1305, 2003). These calculations showed that microbial NAN declined in a step-wise manner, suggesting that an optimum RDP requirement could not be found from this data set. Based on these computations, decreasing RDP from 13.7 to 9.5% reduced microbial NAN flow by 43 g/d. However, the quadratic responses observed for both protein and SNF yield indicated that the optimal dietary RDP concentrations (DM basis) were 11.6% (protein yield) and 10.0% (SNF yield).

Mean metabolite concentrations measured in the rumen when these diets were fed are in Table 3. Ruminal pH, acetate, acetate: propionate ratio, valerate, and branched-chain VFA were not altered by diet. That branched-chain VFA, which are formed from catabolism of branched-chain AA released during protein degradation in the rumen, did not change was surprising in view of the substantial changes in RDP intakes in this trial. As expected, there were linear and quadratic declines in ruminal ammonia, plus a linear decline in free AA, with decreasing RDP. The significant quadratic effect of RDP on ruminal propionate, and the linear and quadratic effects on ruminal butyrate, are difficult to explain. We speculate that the molar proportions of these VFA changed little and the main factor was the quadratic pattern observed in total VFA. Overall, the pattern of ruminal ammonia and total free AA clearly reflected the declining dietary concentrations of RDP.

Summary and Conclusion

Decreasing RDP levels (estimated from NRC, 2001 tables) from 13.7 to 7.5% of dietary DM had significant effects only on milk protein and SNF yield; RDP could be reduced to 9.5%, which reduced urinary N excretion by 33 g/d, without affecting protein production. Concentrations of milk and blood urea, and ruminal ammonia and total free AA, paralleled dietary CP and RDP contents. In this trial, there was a linear decline in microbial NAN flow, estimated from urinary allantoin excretion, as RDP was reduced. However, optimal milk protein yield was predicted from the quadratic response to be 11.6% RDP in dietary DM.

Table 1. Composition of diets.

Item[1]	Dietary RDP, % of DM 13.7	11.6	9.5	7.5
	% of DM			
Corn silage	37.1	37.1	37.1	37.1
Alfalfa silage	12.7	12.7	12.7	12.7
Rolled high moisture shelled corn	32.4	32.1	31.9	31.7
Urea	0.50	0.33	0.17	0
Solvent soybean meal	16.43	10.95	5.48	0
SoyPass[1]	0	5.87	11.74	17.61
Sodium bicarbonate	0.45	0.45	0.45	0.45
Dicalcium phosphate	0.10	0.10	0.10	0.10
Salt	0.25	0.25	0.25	0.25
Vitamin-mineral premix[2]	0.10	0.10	0.10	0.10
Chemical composition[3]				
Crude protein	18.8	18.3	17.7	17.2
NDF	27.5	28.3	27.8	30.0
ADF	16.0	16.4	14.6	15.4
NPN, % of total N	56.6	52.5	48.7	41.4
RDP, % DM	13.7	11.6	9.5	7.5
RUP, % DM	4.9	6.5	8.1	9.7
NE_L, Mcal/kg	1.56	1.55	1.55	1.55
Non-fiber carbohydrate, % DM	49.2	49.9	50.6	51.4
RDP balance, g/d	960	456	-71	-604
RUP balance, g/d	-347	165	546	598

[1]Obtained from LignoTech, Rothschild, WI.

[2]Provided (/kg DM) 56 mg of Zn, 46 mg of Mn, 22 mg of Fe, 12 mg of Cu, 0.9 mg of I, 0.4 mg of Co, 0.3 mg of Se, 6440 IU of vitamin A, 2000 IU of vitamin D, and 16 IU of vitamin E.

[3]NE_L, rumen degraded protein (RDP), and rumen undegraded protein (RUP) values calculated from NRC (2001) tables based on composition of diets fed.

Table 2. Effect of feeding varying levels of rumen degraded protein (RDP) on production, urinary excretion, and estimated microbial NAN flows in lactating cows.

	Dietary RDP, % of DM					Probabilities[1]	
Item	13.7	11.6	9.5	7.5	SE	Linear	Quadratic
DM intake, kg/d	25.1	25.8	25.7	25.6	0.5	0.34	0.21
BW gain, kg/d	0.51	0.58	0.43	0.52	0.13	0.85	0.98
Milk, kg/d	42.0	42.6	42.1	41.4	1.0	0.43	0.34
3.5% FCM, kg/d	35.2	37.1	38.6	37.1	1.9	0.26	0.23
Milk N/N intake, %	29.5	29.8	30.4	30.2	0.9	0.37	0.78
Fat %	3.21	3.38	3.28	3.41	0.15	0.25	0.82
Fat, kg/d	1.23	1.32	1.33	1.31	0.07	0.22	0.23
Protein, %	3.14[a]	3.13	3.07[b]	3.03[b]	0.05	< 0.01	0.63
Protein, kg/d	1.30[a]	1.33[a]	1.30[a]	1.22[b]	0.03	0.02	0.03
Lactose, %	4.75	4.81	4.78	4.83	0.05	0.16	0.90
Lactose, kg/d	1.98	2.06	2.05	1.97	0.06	0.74	0.06
SNF, %	8.78	8.84	8.78	8.76	0.07	0.57	0.43
SNF, kg/d	3.66[ab]	3.79[a]	3.74[a]	3.56[b]	0.09	0.30	0.03
MUNa,[2] mg/dl	12.8[a]	12.9[a]	11.0[b]	10.9[b]	0.5	< 0.01	0.66
MUNc,[2] mg/dl	15.9[a]	15.6[a]	13.6[b]	12.9[b]	0.5	< 0.01	0.55
BUNc,[2] mg/dl	13.8[a]	14.0[a]	11.8[b]	12.4[b]	0.4	< 0.01	0.66
Urinary excretion							
Volume, L/d	22.7[a]	18.4[bc]	19.4[b]	16.8[c]	1.0	< 0.01	0.27
Total N, g/d	288[a]	285[ab]	255[bc]	235[c]	8	< 0.01	0.43
Allantoin, mmol/d	362[a]	333[b]	305[c]	270[d]	12	< 0.01	0.70
Estimated ruminal flows,[3] g/d							
Total purines	348	310	275	229	15	. . .	. . .
Microbial NAN	355	316	280	234	16	. . .	. . .

[a,b,c]LS Means in the same row with different superscripts differ ($P < 0.05$).

[1]Probability of significant linear and quadratic effects of dietary RDP concentration.

[2]MUNa = Milk urea N determined by infrared analysis by AgSource, Verona, WI; MUNc = milk urea N determined colorimetrically; BUNc = blood urea N determined colorimetrically.

[3]Total purines flows computed from urinary allantoin excretion using the equations of Vagnoni et al. (J. Dairy Sci. 80:1691-1701, 1997). Microbial nonammonia N (NAN) flows computed from purine flows using the equations of Reynal et al. (J. Dairy Sci. 86:1292-1305, 2003).

Table 3. Effect of feeding varying levels of rumen degraded protein (RDP) on ruminal metabolites

	Dietary RDP, % of DM					Probabilities[1]	
Item	13.7	11.6	9.5	7.5	SE	Linear	Quadratic
pH	6.28	6.21	6.18	6.26	0.05	0.67	0.06
NH_3, mg/dl	8.81[a]	8.40[a]	6.20[b]	4.08[c]	0.55	< 0.01	0.04
Free AA, mM	4.89[a]	4.51[ab]	3.79[bc]	3.38[c]	0.27	< 0.01	0.95
Total VFA, mM	91.3[a]	81.0[b]	85.9[ab]	92.0[a]	3.9	0.63	0.03
Acetate, mM	55.0	50.9	52.6	56.1	2.2	0.57	0.07
Propionate, mM	21.7[a]	15.5[b]	18.6[ab]	19.7[a]	1.5	0.66	0.01
Acetate: Propionate	2.56	3.49	2.93	3.11	0.26	0.35	0.16
Butyrate, mM	10.0[b]	10.4[b]	9.7[b]	11.5[a]	0.4	0.02	0.04
Isobutyrate, mM	1.25	1.09	1.21	1.13	0.06	0.27	0.44
Isovalerate, mM + 2-methylbutyrate	1.60	1.67	1.8	1.65	0.09	0.49	0.17
Valerate, mM	1.76	1.63	2.02	1.88	0.25	0.16	0.93

[a,b,c]LS Means in the same row with different superscripts differ ($P < 0.05$).

[1]Probability of significant linear and quadratic effects of dietary RDP concentration.

Comparison of Conventional Linted Cottonseed and Mechanically Delinted Cottonseed as Supplements for Multiparous or Primiparous Lactating Dairy Cows

V. R. Moreira, L.D. Satter, and B. Harding

Introduction

Linted whole cottonseed (**LWCS**) is often regarded as a good source of energy, protein and fiber, and for this reason, cottonseed is commonly used in diets of lactating dairy cows. Cotton lint may be removed and used for other purposes in the industry, such as in the production of absorbent cotton, manufacture of diapers, and felts for mattresses, among others. As a result, mechanically delinted whole cottonseed (**DWCS**) has increased in availability for inclusion in dairy diets. Nonetheless, earlier work raised concern over the possibility that DWCS would result in higher fecal loss of intact seeds when compared to LWCS. The objectiveof the study was to compare performance of lactating cows (primiparous and multiparous) fed linted ("fuzzy") or mechanically delinted whole cottonseed, and to determine if the latter resulted in increased loss of whole undigested seeds in feces.

Materials and Methods

Eighty two cows (41 multiparous and 41 primiparous) were divided into two groups and fed similar diets except for whole cottonseed source, which was either linted or mechanically delinted (Table 1). The experiment was divided into two blocks on time because of barn space and cow availability. Each block lasted 18 weeks, with two weeks of standardization period, and 16 weeks of experimental period. Block I included 54 cows, starting on February 12, 2002, and Block II had 28 cows, beginning on April 19, 2002, equally split between multiparous and primiparous for each period. Cows were fed the same diet, which included both sources of cottonseed, during the first 2 weeks (standardization-covariate period) (Table 1). The assignment of cows to either of the treatments was based on milk yield of the second week of the pre-trial period minus that of the last three days, DIM, and parity. Feed intake and milk yield were measured daily from pre-trial until the end of the experimental period. Body weights were measured on two consecutive days, at the beginning and end of each block. Body condition scores were made by two individuals (1 to 5 scale). Three hundred grams of feces were sampled at week 3 and week 13 of the experimental periods to estimate presence of whole cottonseed. Fecal samples were frozen for at least a week before being passed through a set of three sieves (maximum openings of 10.16, 4.35 and 3.07 mm) to collect excreted intact seeds. Results were expressed as percent of fecal dry matter.

Results and Discussion

Results are presented in Table 2. Source of WCS did not affect dry matter intake and milk yield of primiparous nor multiparous cows. Fat yield fell throughout the experiment similarly for LWCS and DWCS, while protein yield rose. There was no difference between treatments. No treatment effect was detected on body condition score of multiparous cows, although DWCS tended ($P \leq .11$) to increase BCS of primiparous cows (0.23 vs. 0.12). Feeding DWCS significantly increased intact seed excretion by primiparous ($P \leq 0.007$) and multiparous ($P \leq 0.001$) cows. Intact seeds were always retained on the sieve with a maximum opening of 4.35 mm. A large amount of cottonseed hulls were observed on the last screen (3.07 mm) with DWCS. Less than 3% of ingested seeds were excreted in the feces. Mechanically delinted cottonseed still retained approximately 4.7% of lint on the cottonseed, while LWCS used in this trial contained 11.7% of lint. It appears that there was suffficient residual lint on the mechanically delinted cottonseed so passage of undigested seeds was minimlly affected.

Conclusion

Feeding either linted cottonseed ('fuzzy') or delinted whole cottonseed did not affect performance of dairy cows. The passage of intact seeds into the feces was small with delinted whole cottonseed, 2.5% of consumed seeds appeared in the feces. With linted cottonseed, 1.5% of consumed seeds were in the feces.

Table 1.

Ingredients:	Pre-trial Period	Treatment diets	
		DWCS	LWCS
Corn silage	28.1	28.1	28.1
Alfalfa silage	23.0	23.0	23.0
High moisture shelled corn	27.8	27.8	27.8
Linted whole cottonseed	6.5	0.0	13.0
Delinted whole cottonseed	6.5	13.0	0.0
Soybean meal (48%CP)	1.8	1.8	1.8
Soy-plus®	1.8	1.8	1.8
Blood meal	2.0	2.0	2.0
Salt (NaCl)	0.3	0.3	0.3
Limestone	1.0	1.0	1.0
Dicalcium-phosphate	0.4	0.4	0.4
Sodium bicarbonate	0.7	0.7	0.7
Vitamin-mineral supplement	0.1	0.1	0.1
Chemical Analyses:			
DM (%)	57.5 ± .04	59.2 ± 1.82	59.3 ± 1.76
CP (%DM)	16.5 ± .05	16.3 ± .02	16.2 ± .12
NDF (%DM)	29.8 ± .19	28.9 ± .76	29.2 ± .71
ADF (%DM)	18.6 ± .27	17.6 ± .56	18.4 ± .57
Ether extract (%DM)	5.23 ± .21	5.05 ± .06	5.40 ± .11

Table 2.

	MULTIPAROUS			$P\leq$		
	DWCS[1]	LWCS[2]	SEM	Lint	Week	Lint*Week
DMI (kg/d)	23.8	23.1	1.60	0.14	<.001	<.001
Milk Yield (kg/d)	37.4	37.5	0.83	0.91	<.001	0.68
Fat, kg/d	1.17	1.15	0.11	0.84	<.001	0.88
True protein, kg/d	1.06	1.06	0.03	0.87	<.001	0.71
Body weight change (kg/d)	30.2	26.0	9.87	0.76	-	-
BCS change	0.27	0.31	0.05	0.54	-	-
Intact seeds, % fecal DM	1.53	0.72	0.15	<.001	0.92	0.009
	PRIMIPAROUS			$P\leq$		
	DWCS[1]	LWCS[2]	SEM	Lint	Week	Lint*Week
DMI (kg/d)	20.5	20.4	0.59	0.83	<.001	<.001
Milk Yield (kg/d)	32.7	32.8	0.78	0.88	<.001	0.96
Fat, kg/d	1.06	1.03	0.06	0.47	<.001	0.38
True protein, kg/d	0.98	0.95	0.02	0.18	0.11	0.81
Body weight change (kg/d)	2.0	-9.6	133.0	0.60	-	-
BCS change	0.22	0.11	0.45	0.11	-	-
Intact seeds, % fecal DM	1.02	0.61	0.10	0.007	0.90	0.65

Effect of Dietary Phosphorus Concentration on Estrous Behavior of Lactating Dairy Cows
H. Lopez, Z. Wu, L.D. Satter and M.C. Wiltbank

Introduction

There is a widespread notion that increasing dietary phosphorus (P) can improve 'strength of heat' in lactating dairy cows. Extremely low dietary P (< than 0.25% of diet DM) can reduce microbial activity in the rumen, which in turn can reduce digestibility of the diet and reduce microbial synthesis of protein. Reduced energy and protein status can definitely interfere with reproductive performance. The objective of this study was to measure the effect of dietary P concentrations of 0.38 (adequate) or 0.48% (excess) on estrous behavior of lactating cows as measured by a radiotelemetric system (Heatwatch).

Material and Methods

Observations on estrous behavior presented in this report were collected during the first year of a two-year trial that analyzed milk production and reproductive performance of dairy cows fed two concentrations of dietary P (Wu and Satter, JDS 83:1052). Cows were fed either a diet that was close to the NRC recommendations (0.38% P=adequate), or a diet that was in excess of the NRC recommendations (0.48% P=excess). Formulation of the TMR was the same for both groups. The low P diet contained no supplemental P, while the high P diet was obtained by adding monosodium phosphate and dicalcium phosphate to the TMR. At calving each cow was randomly assigned to one of the dietary treatments. All animals were housed in a free-stall barn with concrete flooring and fed the TMR ad libitum during the first 34 weeks of lactation (September to May).

Forty-two Holstein cows (n=21 per dietary treatment, including 10 primiparous animals in each group) were used to characterize estrous behavior. Animals were fitted with a radiotelemetric patch and a transmitter on d 40 postpartum. This system was used to collect information on mounting activity related to estrous. Activation of the pressure-sensitive transmitter by the weight of a mounting cow for a minimum of 2 s interrupts a radio-wave transmission generating real time data. Estrous behavior was characterized only by the information collected by the radiotelemetric system. Onset of estrus was identified by the first activation of the transmitter. Duration of estrus was defined as the time interval from the first to last mount recorded during an estrous period, thus excluding an estrus consisting of only one mount.

Visual detection of estrus was performed during the day and while cows were in the holding area prior to milking. Cows were inseminated at the first estrus detected by visual observation after 52 d postpartum following the AM-PM rule. Pregnancy was confirmed by rectal palpation approximately 30 d after insemination.

Results and Discussion

Dietary P had no detectable effect on the length of estrus, the number of mounts per estrus, or the mounting time. Dietary treatment also had no effect (P=0.66) on duration and intensity of estrus (Table 1).

Estrous characteristics in relation to milk production were analyzed. In order to perform this analysis, average milk production for the five days preceding the day of estrus, as identified by radio telemetry, was calculated. This average was used to classify cows as low (< 35.1 kg/d) or high (> 35.1 kg/d) producers. The results are in Table 2.

In lactating dairy cows, the continuous high plane of nutrition needed to meet the requirements of high production appears to increase liver blood flow and the metabolic clearance rate of (P_4) and (E_2) (Sangsritavong et al., J. Dairy Sci. 85:2831). This leads to lower circulating concentrations of steroids in high producing cows with consequent alterations in the normal reproductive processes (Wiltbank et al., JDS 84(Suppl. 1):32). The expression of estrus is induced by high systemic concentrations of E_2 produced by the pre-ovulatory follicle. Thus, the lower peak concentration of E_2 and perhaps a more rapid decrease in E_2 after the onset of estrus could cause cows to display estrus for a shorter time and with less intensity than those displayed by lower producers.

Conclusion

Dietary P concentration has no effect on characteristics of estrus, but milk production had a strong negative correlation with duration of estrus.

Table 1. Characteristics of estrous behavior (mean ± SEM [range]) for cows fed diets containing Low (0.38%) or High (0.48%) P.

Characteristic[1]	Low P (n=37)	%	High P (n=35)	%	P-value
Duration of estrus, h	8.9±1.1		8.6±1.2		0.86
Total mounts, n	7.0±1.2		8.2±1.7		0.57
Total mounting time, s	27.1±4.3		30.8±6.5		0.64
Short duration, low intensity[1]	13	35.1	15	42.8	
Short duration, high intensity[1]	9	24.3	6	17.2	
Long duration, low intensity[1]	12	32.4	9	25.7	
Long duration, high intensity[1]	3	8.2	5	14.3	

[1]Estruses were classified by duration as short (< 8.8 h) or long (≥ 8.8 h). Short estruses were classified as low (< 1.6 m/h) or high (≥ 1.6 m/h) intensity and long estruses as low (< 0.8 m/h) or high (≥ 0.8 m/h) intensity.

Table 2. Characteristics of estrous behavior (mean ± SEM [range]) for low (< 35.1 kg/d) and high (≥ 35.1 kg/d) producing cows.

Characteristic[1]	Low milk (n=33)	%	High milk (n=39)	%	P-value
Average milk production, kg/d	28.0±0.8		40.4±0.8		< 0.0001
Duration of estrus, h	11.1±1.5		6.9±0.8		0.01
Total mounts, n	10.0±2.1		5.5±0.6		0.03
Total mounting time, s	38.9±7.6		20.4±2.6		0.02
Short duration, low intensity[1]	7	21.2	21	53.8	
Short duration, high intensity[1]	10	30.3	5	12.8	
Long duration, low intensity[1]	12	36.4	9	23.1	
Long duration, high intensity[1]	4	12.1	4	10.3	

[1]Estruses were classified by duration as short (< 8.8 h) or long (≥ 8.8 h). Short estruses were classified as low (< 1.6 m/h) or high (≥ 1.6 m/h) intensity and long estruses as low (< 0.8 m/h) or high (≥ 0.8 m/h) intensity.

Effect of Dietary Phosphorus Concentration on Reproductive Performance of Lactating Dairy Cows

H. Lopez, F.D. Kanitz, V.R. Moreira, M.C. Wiltbank and L.D. Satter

Introduction

It is common for dairy producers to increase dietary phosphorus (P) above NRC requirements in an attempt to improve reproductive performance of the herd. The objective of this study was to determine the effect of dietary P concentrations of 0.37% or 0.57% of the TMR (DM basis) on reproductive performance.

Materials and Methods

This study used 267 cows (131 primiparous and 136 multiparous) that were fed either an adequate (0.37%) or an excessive P diet (0.57%) beginning at calving and continuing for 165 days of lactation. Milk weights were recorded at each milking, and blood samples were obtained near day 50 and day 100 post partum for P analysis. Weekly blood samples were used for progesterone (P_4) analysis. Days to first increase in P_4 concentration above 1 mg/ml was determined from the weekly blood samples and used as an indication of first natural ovulation. Cows were fitted with a radiotelemetric transmitter (HeatWatch) at day 50. Cows were bred to natural estrous from day 50 to day 100 and to synchronized estrous after day 100. Weekly ultrasonography was performed from day 50 until the cow was pregnant. Days to first natural estrus were determined from data collected by HeatWatch. A cow was determined to be in anovulatory condition if no new CL was detected during a period of at least three weekly consecutive ultrasound examinations. No treatment was given to anovulatory cows between 50 to 100 days postpartum. After 100 days postpartum anovulatory cows were treated with the Ovsynch protocol.

Results and Discussion

Blood serum P concentrations for the low P diet at day 50 and 100 postpartum were 6.1 and 6.2 mg/dl. Comparable values for the high P diet were 6.8 and 6.9 mg/dl. Treatment effect was highly significant. Milk production, milk composition and body condition score are in Table 1. There were no significant treatment effects.

Characteristics of estrous behavior are in Table 2 and various measurements of reproductive performance are in Table 3. Dietary P had no effect on any of the reproductive measures made.

Characteristics of estrous events for low (<39.5 kg/d) and high (>39.5 kg/d) producing cows is shown in table 4. Level of milk production, in contrast to dietary P content, had a large impact on estrous behavior.

Conclusion

Increasing dietary P above the NRC requirement had no detectable effect on behavioral estrous or any other reproductive measure. In contrast, milk production level had a dramatic impact on estrous behavior.

Table 1. Least squares means for milk production, milk components and body condition score of lactating dairy cows fed diets containing 0.37% or 0.57% dietary P.

	Dietary P content (%)				
	0.37		0.57		
Item	Mean	SE	Mean	SE	P[2]
Number of cows	123		124		
Milk Yield[1] (kg/day)	35.1	0.52	34.9	0.52	NS
3.5% FCM (kg/day)	36.8	0.65	36.9	0.64	NS
Milk Composition Fat (%)	3.92	0.04	3.98	0.04	NS
Protein (%)	2.90	0.02	2.91	0.02	NS

[1]First 165 days of lactation
[2]NS=*P*>0.30

Table 2. Characteristics of estrous behavior for lactating cows fed diets containing 0.37% g or 0.57% g P.

` Characteristic[1]	0.37 g P/kg (n=159)	0.57 g P/kg (n=174)	*P*
Duration of estrus, h[2]	8.7±0.5	8.7±0.6	0.99
Total mounts, n	7.5±0.5	7.8±0.5	0.68
Total mounting time, s	25.8±1.8	24.5±1.5	0.59
Average duration of standing events, s	3.4±0.2	3.4±0.2	0.76

[1]Estruses consisting of only one standing event were removed from the analysis.
[2]Number of hours between the first and the last recorded mount of an estrous period

Table 3. Reproductive parameters for lactating cows fed diets containing 0.37% g or 0.57% P.

	0.37 % P	0.57 % P	*P*
Days to first P_4 increase[1]	53 ± 3	53 ± 3	0.97
Days to first natural estrus[2]	68 ± 1.1	67 ± 1.2	0.87
Days to first service	89 ± 2.0	90 ± 2.0	0.87
Conception rate at first AI[3], %	39.4	42.0	0.67
Overall conception rate at 30 d[4], %	34.3	38.0	0.35
Overall conception rate at 60 d, %	29.1	31.8	0.47
Pregnancies lost (30 to 60 d), %	15.2	16.2	0.83
Pregnancies lost after 60 d, %	6.0	5.4	0.87
Days open	112 ± 3.5	116 ± 3.8	0.45
Services/conception[5]	2.9	2.6	0.35
Double ovulation rate, %	19.9	18.4	0.66
Anovulatory condition[6], %	29.9	27.1	0.61

[1]First increase in progesterone concentration >1 ng/ml.
[2]First natural estrus detected by the Heatwatch system between 50 and 100 d.
[3]Number of pregnancies detected at 30 d divided by the number of first services.
[4]Number of pregnancies detected at 30 d divided by the total number of services.
[5]Total number of services divided by the number of pregnancies detected at 30 d.
[6]Cows with no new CL for at least three weekly consecutive ultrasound examinations after d 50.

Table 4. Characteristics of estrous events (mean ± SEM [range]) for low (<39.5 kg/d) and high (>39.5 kg/d) producing cows

Characteristic	Low producers (n[1]=177)	High producers (n=146)	P-value
Average milk production[2], kg/d	33.5 ± 0.3	46.4 ± 0.4	<0.0001
Duration of estrous[3], h	10.9 ± 0.7	6.2 ± 0.5	<0.0001
Total mounts, n	8.8 ± 0.6	6.3 ± 0.4	0.001
Total mounting time, s	28.2 ± 1.9	21.7 ± 1.3	0.007
Average days in milk[4], d	95.8 ± 2.7	90.9 ± 2.8	0.21

[1]Number of estrous events.
[2]Average milk production for the 10 d before the day of estrous.
[3]Number of hours between the first and the last recorded mount of an estrous period.
[4]Days postpartum when information on estrous behavior was collected by radiotelemetry.

Effect of Dietary Protein Content and Alfalfa: Corn Silage Ratios on Nitrogen Excretion and Milk Production of Late Lactation Cows

H.H.B. Santos, S. Lardoux, V.R. Moreira, and L.D. Satter

Introduction

Increasing concerns about ammonia and nitrous oxide emissions from livestock and poultry facilities to the atmosphere are stimulating measures to reduce total nitrogen (N) excretion through diet manipulation, and more specifically, to decrease urinary N. Rapid conversion of urinary urea to ammonia makes the N in urine particularly susceptible to volatile losses. The objective of this study was to evaluate the effect of different dietary protein concentrations and alfalfa: corn silage proportions in the diet on nitrogen distribution between milk, feces, and urine of late lactation cows.

Materials and Methods

Twenty-four cows (12 multiparous and 12 primiparous) were randomly assigned to a 6x6 Latin square design with 14-d periods. Treatments were arranged in a factorial design with two alfalfa silage: corn silage ratios (70:30 and 30:70) and three levels of crude protein (~ 15, ~ 16.5, and ~ 18%). Roasted soybeans and soybean meal replaced high moisture corn to increase dietary protein content. Feed intake was measured daily and analyzed for DM, CP, NDF, ADF, and marker (ytterbium) concentration. Milk yield was recorded daily and sampled at the end of each period. Urine samples were obtained at 4hr-intervals during the last day of each period and 12 rectal fecal samples were obtained during the last 3 days from each cow on every even hour of the 24-hr period. Fecal marker and urinary creatinine concentrations were used to calculate N excretion in feces and urine. Diet ingredients are shown in Table 1.

Results and Discussion

Dry matter intake was slightly lower for the 15% CP treatment than for the 16.5 and 18.0% CP treatments (Table 2). Milk production and milk nitrogen followed a similar pattern. Somewhat surprisingly, milk protein content averaged slightly higher for the high alfalfa diets than for the high corn silage diets. Milk fat (%) was unaffected by diet treatment. Fecal N increased some with an increase in dietary N, but most of the incremental increase in dietary N ended up in urinary N.

Conclusion

The lowest level of dietary protein (~ 15%) caused a slight reduction in milk production, whereas ~ 16.5% crude protein was sufficient to maintain normal milk production for the late lactation cows used in this study. Most of the protein fed in excess of the requirement was excreted in the urine. Results support the NRC (2001) protein recommendation.

Table 1. Diet composition

Diet (% DM)	Diet 1 70/30 AS/CS 14.9% CP	Diet 2 70/30 AS/CS 16.5% CP	Diet 3 70/30 AS/CS 18.1% CP	Diet 4 30/70 AS/CS 15.4% CP	Diet 5 30/70 AS/CS 16.9% CP	Diet 6 30/70 AS/CS 18.5% CP
Normal corn silage	19.50	19.50	19.50	45.50	45.50	45.50
Alfalfa silage early cut	45.50	45.50	45.50	19.50	19.50	19.50
Beet pulp	4.00	4.00	4.00	4.00	4.00	4.00
HMSC	28.80	25.55	21.00	16.50	12.35	9.10
Roasted Soybean	0.00	2.50	7.25	8.00	9.00	9.00
Soybean meal 48	0.00	0.00	0.00	2.75	6.40	9.75
Blood meal	0.70	1.50	1.50	1.50	1.00	1.00
Limestone	0.00	0.00	0.00	1.00	1.00	1.00
Sodium bicarbonate	0.75	0.75	0.75	0.75	0.75	0.75
Dicalcium phosphate	0.65	0.60	0.40	0.40	0.40	0.30
Vit TM Pak	0.10	0.10	0.10	0.10	0.10	0.10
	100.00	100.00	100.00	100.00	100.00	100.00
Forage/concentrate Ratio	65/45	65/45	65/45	65/45	65/45	65/45
Protein supply compared to NRC (2001) requirements						
RUP req'd	904	985	962	970	896	880
RUP supplied	761	950	1121	1048	1198	1304
RDP req'd	1912	1935	2025	1911	1996	1974
RDP supplied	2107	2269	2573	1857	2168	2331

Table 2. Cow performance

Forage ratio	AS:CS (70:30)			AS:CS (30:70)				P <			
Dietary protein, %	14.9	16.5	18.1	15.4	16.9	18.5	SEM	AS vs CS	15 vs 16.5	15 vs 18	16.5 vs 18
DMI, kg/d	19.3	19.5	20.4	18.9	19.9	19.7	0.44	0.31	0.03	0.01	0.21
Milk, kg/d	26.5	27.9	28.4	27.7	28.2	28.0	0.62	0.21	0.01	0.01	0.72
Milk fat, %	3.72	3.84	3.84	3.88	3.83	3.78	0.09	0.29	0.35	0.76	0.52
Milk CP, %	3.09	3.05	2.98	2.99	3.03	3.00	0.04	0.01	0.93	0.01	0.01
N Intake, g/d	460	516	592	465	537	582	11.7	0.38	0.01	0.01	0.01
Milk N, g/d	131	136	136	132	138	136	3.47	0.45	0.01	0.01	0.62
Fecal N, g/d	188	186	212	176	198	204	9.08	0.48	0.03	0.01	0.01
Urine N, g/d	167	193	210	145	184	221	6.33	0.13	0.01	0.01	0.01
Milk N,% NI	28.5	26.4	23.0	28.4	25.7	23.4	0.52	0.64	0.01	0.01	0.01
Recovered N, % NI	106.0	100.1	94.9	98.2	97.1	96.6					

FIBEX-Pretreated Rice Straw as a Feed Ingredient for Lactating Dairy Cows
P.J. Weimer, D.R. Mertens, E. Ponnampalam, B.F. Severin, and B.E. Dale

Introduction

Rice straw is an abundant product of rice production. In northern California, rice straw has traditionally been disposed of by field incineration, but air quality issues and recent changes in state law now allow such burning only on a permit basis in cases where control of plant disease is necessary. Alternate uses have been proposed for the large volumes of rice straw generated, but none have been commercialized. Because of its high ash content and the low digestibility of its organic matter, rice straw is not considered useful as an animal feed without a pretreatment to upgrade its digestibility. One potential pretreatment is the proprietary FIBEX process, which involves continuous treatment of the straw with ammonia under temperature and pressure, with subsequent rapid release of the pressure that causes a "freeze explosion" of the straw fibers. The FIBEX process is thought to enhance digestibility by breaking phenolic-carbohydrate bonds and by increasing the surface area of the substrate. Because essentially all of the ammonia can be recovered, there is no appreciable liquid residue that would represent a disposal problem. The purpose of this study was to determine: a) if FIBEX pretreatment improves the kinetics of digestion of rice straw by mixed ruminal microbes in vitro; and b) if the pretreated rice straw supports milk production when incorporated into dairy rations at a modest level (7% of DM).

Methods

Rice straw was produced at bench scale at the Michigan Biotechnology Institute. Individual samples of rice straw (DM 60-82%) were sprayed with ammonia (0.5-1.0 g NH_3/g DM), placed in a pressure vessel and heated to 87-108 ^{o}C over the course of 5-10 min, after which the pressure (19-26 atm) was rapidly released. To prepare material in amounts needed for a feeding trial, several tons of rice straw were pretreated (0.3 g NH_3/g,110-132 ^{o}C, 12.9-15.0 atm) in a Sunds defibrator at the Tennessee Valley Authority pilot plant in Muscle Shoals, AL.

In vitro digestion experiments were conducted in sealed 60 mL vials of precisely-known volume, that contained 100 mg of substrate, 8 mL of cysteine-reduced Goering-Van Soest buffer, 2 mL of ruminal inoculum composited from two cows, and a CO_2 gas phase. Digestion kinetics were determined by automated recording (~ 150 time points) of gas pressure in sealed vials over a 72 h period. After correction for gas produced in sealed blank vials that contained ruminal inoculum but no rice straw, gas production data were fitted to an two-pool exponential model to determine the lag time, first-order rate constant, and extent of gas production for both the rapidly-digesting and slowly-digesting substrate pools.

The feeding trial was conducted with 20 lactating Holstein cows in a switchback design having 21d periods. Control diet © and Rice-straw amended ® diets (35.8% NDF, 25.9% ADF and 18% CP) were formulated to meet NRC requirements, and contained alfalfa hay, corn grain and soybean meal, along with byproduct feeds typically used in northern California, Table 1. Feed samples and orts (collected daily and were composited by cow) were analyzed for NDF and ADF. Milk yield was determined from twice-daily milkings, and milk composition was determined by NIR (Ag-Source, Verona, WI).

Results and Discussion

In vitro fermentations. Gas production from untreated rice straw lagged behind that of inoculated vials lacking substrate, suggesting the presence of a fermentation inhibitor in the rice straw. The slowly digested substrate pool of untreated rice straw was eventually fermented with a lag time of 10.4 h, and a first-order rate constant of 0.035/h, while the slowly-digested pool of the eleven bench-scale pretreated rice straw samples were fermented with a lag time of 6.4-7.4 h and first-order rate constants of 0.50-0.61/h. Total gas yield from the fermentation of untreated and pretreated rice straws were 129.3 and 127.0-191.7 mL/g OM, respectively.

Production trial. One of the R cows stopped eating a few days into the trial and so was removed. The other cows readily ate both rations without visible sorting, and without any display of hyperexcitability that has been reported consuming high levels (50% of DM) of ammonia-treated rice straw. Feeding of ration R resulted in increases ($P<0.05$) in both NDF intake and milk yield that averaged 1.1 and 1.3 kg/d, respectively (Table 2). A decline in milk fat content of 0.3% occurred with ration R, perhaps in response to the small particle size of the rice straw. Despite higher levels of inorganic N in the pretreated rice straw, levels of protein and MUN in the milk did not differ between treatments.

Conclusions

Pretreatment of rice straw by the FIBEX process reduced the lag time prior to the onset of fermentation and substantially increased the rate of digestion of the fiber fraction, and the total amount of substrate fermented. The enhanced digestion in vitro was reflected in an ability of the pretreated rice straw to sustain milk production when added to 7% of DM in a properly balanced ration. The FIBEX process may this provide a means of converting rice straw, a nuisance agricultural residue, to a useful fiber and energy source of lactating dairy cows.

Table 1. Formulated composition of control diet and diet amended with FIBEX-treated rice straw

	Control	Rice straw
Ingredient composition (g/kg DM) [a]		
Alfalfa hay	450	350
Corn grain, dry kernel	183	206
Whole linted cottonseed	120	120
Treated rice straw	--	70
Beet pulp, pelleted	80	80
Corn gluten feed, dehydrated	80	80
Wheat middlings	40	40
Soybean meal, 48% CP solvent	23.5	29.5
Beet molasses, liquid	20	20
Monosodium phosphate	1.0	1.8
Magnesium oxide	1.3	1.6
Salt and vitamin mixture [b]	1.0	1.0
Chemical composition (g/kg DM)		
NDF	358	357
ADF	258	258
CP	180	180
Ash	70	70
Ca	8.4	7.1
Mg	3.5	3.5
P	4.1	4.1

[a] Dry matter content was 89.7% for the control diet and 89.5% for rice straw diet.
[b] TM Vit Pak (Professional Products and Services, Prairie du Sac, WI, USA) contained per g: 229 mg Ca, 56 mg Zn, 46 mg Mn, 22 mg Fe, 12 mg Cu, O.4 mg Co, 0.9 mg I, 0.32 mg Se, 7084 IU vitamin A, 2200 IU vitamin D3, 17.6 IU vitamin E.

Table 2. Feed intake and production of cows fed diets with and without FIBEX-treated rice straw.

	Control	Rice	Pooled S.E.	*P* > F
Intake (kg/d):				
DM	25.0	25.9	2.9	0.151
OM	22.0	22.9	2.1	0.199
NDF	7.0	8.1	0.7	<0.001
ADF	5.2	5.3	0.5	0.349
CP	4.0	4.0	0.1	0.804
Production (kg/d):				
Milk	38.3	39.6	1.6	0.020
Fat	1.47	1.41	0.11	0.062
Protein	1.14	1.19	0.05	0.011
Lactose	1.83	1.86	0.19	0.671
Energy [a] (MJ/d)	114.0	113.6	6.1	0.914
Milk composition (%):				
Fat (%)	3.86	3.55	0.22	<0.001
Protein (%)	2.99	3.00	0.10	0.664
Lactose (%)	4.77	4.82	0.11	0.197
Urea N (mM)	5.11	5.29	0.83	0.626

Corn Silage Maturity and Processing: 1. Effects on Production of Dairy Cows

D.R. Mertens, G. Ferreira, P. Berzaghi, and R.D. Shaver

Introduction

The effect of maturity on the nutritive value of corn silage is unique among forages. The energy value of corn silage typically declines slowly with maturity because the beneficial effects of increased proportion of grain often diminish the detrimental effects of lignification and maturation of the stover. However, the benefit of a high proportion of grain in mature corn silage depends on adequate digestion of the starch. Starch may not be utilized efficiently unless it is adequately ground or chewed. Kernel processors, which pass the harvested corn through rollers with 1-mm clearances, were introduced to crush kernels and insure maximum digestion of starch. At later stages of maturity, corn kernels harden and develop complex matrices that can reduce starch digestion; thus processing corn silage should be more beneficial for mature corn silages. The objective of this experiment was to evaluate the effects of corn silage maturity and processing on intake and lactation performance by cows of different stages of lactation.

Materials and Methods

Forty-eight lactating Holstein cows were blocked by stage of lactation (**mid** or **late**) and parity (1st, 2nd or ≥3rd) and assigned to replicated 4 x 4 Latin squares (28-d periods) with a 2 x 2 factorial arrangement of treatments: early (**E**) or late-maturity (**L**), and processed (**P**) or unprocessed (**U**) corn silages. Mid lactation cows averaged 73 and late lactation cows averaged 455 day in lactation at the beginning of the experiment. The corn hybrid was corn hybrid Dairyland Stealth 1412 and silage dry matter (**DM**) concentrations were 33.5 and 41.8% for the E and L corn silages, respectively. Corn was processed using a 1-mm roller clearance and the theoretical length of cut (**TLC**) was set at 1.90 and 2.54-cm for unprocessed and processed treatments to reduce the effects of processing on particle size. The amylase-treated NDF (**aNDF**) and starch concentrations of the corn silages were: 36.7, 28.0; 38.1, 26.3; 34.0, 37.3; and 35.4, 35.1% for EU, EP, LU, and LP, respectively. Diets were composed of 70% corn silage and 30% concentrate and averaged 17% CP and 28% NDF.

Results and Discussion

Processing during harvesting crushed kernels effectively as indicated by the percentage of starch >4.75 mm in particle size, which is an index of processing effectiveness. The percentages of starch >4.75 were 58.8 and 42.2 for EU and LU, respectively, which was reduced to 11.9 and 7.7% for processed silages EP and LP, respectively. The reduction in starch >4.75-mm for L compared to E whether processed or not was surprising and may be related to greater brittleness or friability of kernels that were more mature. Although the TLC was increased to compensate for the reduction in particle size due to processing, the lognormal mean particle sizes of processed silages were lower: 4.1, 3.1, 4.1, and 2.7 mm for EU, EP, LU, and LP, respectively. This occurred because cobs and kernels were reduced in size substantially by processing.

Dry matter intake (**DMI**) was greater for mid lactation cows when fed later maturity silages, but processing silages had no effect on intake (Table 1). Neither processing nor maturity of the silage affected milk production of mid lactation cows. Milk fat percentage was higher for mid lactation cows consuming early maturity silages, which resulted in a tendency for 3.5% fat-corrected milk (3.5% FCM) production to also be higher for early maturity silages. Milk protein percentage of mid lactation cows was higher when consuming processed silages.

The DMI of late lactation cows was higher when fed processed silages, primarily to differences between EU and EP. Milk production and composition of late lactation cows was not affected by silage maturity or processing, except that 3.5% FCM was higher for cows fed processed silage. Similar to mid lactation cows, there was a tendency for milk fat percentage to be higher when late lactation cows consumed E silages that were slightly higher in fiber and lower in starch than L silages. The main response of late lactation cows was to increase average daily gain when fed processed silages, although maturity had no effect on the gain of these cows.

Conclusions

Corn silage maturity and processing did not result in large differences in intake and production when fed as 70% of the ration dry matter to cows in mid and late lactation. There was no maturity by processing interaction in cow performance suggesting that processing did not improve the nutritive value of late maturity silage to a greater extent than for early maturity as was postulated. This may be related to the greater friability of corn kernels in the late maturity corn silage as indicated by the smaller proportions of starch that were >4.75-mm in size.

Table 1. Intake and yield of milk and milk components of cows fed diets containing corn silages harvested at two maturity stages with or without kernel processing (least square means).

Cow group	Corn silage[1]					Probability of differences[2]		
Performance	EU	EP	LU	LP	SEM	M	P	M × P
Mid lactation cows								
DM intake, kg/d	21.2	22.0	23.9	23.3	1.61	.042	.911	.372
Production, kg/d								
Milk	32.5	33.6	32.2	33.5	1.47	.880	.327	.941
3.5% FCM	33.2	33.7	32.3	31.7	1.48	.138	.962	.506
Milk composition, %								
Fat	3.62	3.60	3.54	3.28	0.18	.053	.128	.184
Protein	3.03	3.17	3.08	3.11	0.05	.881	.045	.157
Body weight gain, kg/d	0.36	0.57	0.36	0.33	0.13	.367	.463	.339
Late lactation cows								
DM intake, kg/d	18.8	22.8	21.2	21.5	0.95	.431	.033	.019
Production, kg/d								
Milk	13.5	15.1	14.2	14.0	2.29	.738	.252	.145
3.5% FCM	14.5	17.0	15.2	15.2	2.45	.298	.046	.036
Milk composition, %								
Fat	4.33	4.19	4.00	4.07	0.24	.208	.832	.538
Protein	3.83	3.84	3.81	3.75	0.16	.540	.773	.671
Body weight gain, kg/d	0.50	0.97	0.64	0.97	0.12	.679	.025	.614

[1] EU = Early Unprocessed; EP = Early Processed; LU = Late Unprocessed; and LP = Late Processed.

[2] M = Maturity main effect (E vs. L); P = Processing main effect (U vs. P); and M × P = Maturity by Processing interaction.

Corn Silage Maturity and Processing: 2. Effects on Fiber and Starch digestion by Dairy Cows
D.R. Mertens, G. Ferreira, P. Berzaghi, and R.D. Shaver

Introduction

Digestibility of forages is affected not only by their maturity and composition, but also by the level of intake of the animal that consumes them. In general, the digestibility of forages declines with maturity, in part, because more mature plants have more cell walls that are more lignified. Corn silage it unique because the grain that accumulates during maturation is more digestible than cell walls, which often counteracts the lower digestibility of the stover. It is not uncommon for digestible starch to comprise 50 to 70% of the total digestible nutrients in corn silage. Processing corn during harvesting should fracture kernels and maximize starch digestion, especially in mature corn silages that contain starch that is protected by hard seed coats and complex granule matrices. However, few studies have evaluated if processing is more beneficial in mature corn silage (or determined if the level of intake of corn silage has a significant impact on the digestion of corn silage). The objective of this experiment was to evaluate the effects of animal intake and corn silage maturity and processing on the digestion of nutrients by lactating cows.

Materials and Methods

Forty-eight lactating Holstein cows were blocked by stage of lactation (**mid** or **late**) and assigned to replicated 4 x 4 Latin squares with a 2 x 2 factorial arrangement of treatments: early (**E**) or late-maturity (**L**), and processed (**P**) or unprocessed (**U**) corn silages. Mid lactation cows averaged 73 and late lactation cows averaged 455 days in lactation at the beginning of the experiment. Late lactation cows were selected to measure digestibilities at low ad libitum intakes. Silage dry matter (**DM**) concentrations were 33.5 and 41.8% for the E and L corn silages, respectively. Corn was processed using a 1-mm roller clearance and the theoretical length of cut was set at 1.90 and 2.54-cm for unprocessed and processed treatments. Diets were composed of 70% corn silage and 30% concentrate. The rare earth, lanthanum, was used as an external marker to measure digestibility. Fecal grab samples were collected across three consecutive days (starting on day 26 of each 28-d period) at 6-h intervals, shifting two hours at the end of each day so that samples were collected at 2-h intervals during a 24-h feeding cycle.

Results and Discussion

Corn silages contributed about 90% of the amylase-treated NDF (aNDF) and 80% of the starch in their respective rations (Table 1). The aNDF concentration was slightly higher and the starch concentration slightly lower for rations containing processed silage due to a maladjusted processor cover that allowed starch loss during harvesting. Although mature corn silage contained more starch, it was more susceptible to processing so the starch in particles >4.75 mm were very similar within P and U treatments, i.e., 16.7, 3.0, 15.7, and 2.7% for EU, EP, LU, and LP silages, respectively.

Dry matter intake did not differ between cows in mid and late lactation as was expected. Although late lactation cows had a lower nutrient demand for lactation, they tended to gain weight and consume rations in similar amounts to mid lactation cows. Dry matter digestibility (**DMD**) tended to be higher for diets containing E compared to L corn silages (71.4 vs. 69.8%) when consumed by mid lactation cows, but not when consumed by late lactation cows (71.2 vs. 71.4%), Table 2. The difference in DMD between maturities was due primarily to differences in aNDF digestibilities (**aNDFD**). When mid lactation cows consumed silages, the aNDFD was significantly different (49.2% for E compared to 39.7% for L). The difference in aNDFD was significant, but much lower for late lactation cows (51.2 and 45.7% for E and L, respectively), which may explain the lack of difference in DMD for these cows. When averaged across processing treatments, maturity did not affect starch digestibility (**StarchD**) for either mid or late lactation cows (95.3 and 94.8% for E and L, respectively). For unprocessed silages, the average StarchD for all cows was 92.8 and 91.0% for E and L, respectively.

Processing corn silage improved the DMD for both mid and late lactation cows, averaging 69.0 and 72.9% for U and P, respectively. This response was primarily due to increased StarchD for P compared to U (98.2 vs. 91.9%) for both groups of cows. The aNDFD was also higher for P compared to U, but the difference was significant only for the mid lactation cows.

Conclusions

Both maturity and procession affect the digestibility of corn silages. The early maturity corn silage (DM = 33.5%) was more digestible than the late maturity (DM = 41.8%) and processing increased the digestibilities of dry matter, starch, and to a lesser extent aNDF. However, processing did not improve the digestibilities of mature corn silage to a greater extent than for more immature silages. There was some indication that the effects of maturity and processing on aNDFD were confounded by changes in the starch concentration in the ration. A review of published results suggests a significant negative effect for the ratio of starch to NDF intake on fiber digestibility.

Table 1. Nutrient composition of experimental rations.

	Corn silage used in the rations[1]			
	EU	EP	LU	LP
Dry Matter, %	41.4	41.6	49.9	49.9
Crude protein, % DM	17.5	17.7	17.6	17.6
aNDF, % DM	28.0	28.9	26.1	27.0
Starch, % DM	24.1	22.8	30.6	29.0
aNDF from corn silage, % ration aNDF	91.0	91.2	90.4	90.7
Starch from corn silage, % ration starch	80.7	79.4	84.8	83.9

[1] EU = Early Unprocessed; EP = Early Processed; LU = Late Unprocessed; LP = Late Processed.

Table 2. Nutrient intake and apparent total-tract digestibility by cows in mid lactation fed diets containing corn silages harvested at two maturity stages with or without kernel processor (least square means).

Cow group	Corn Silage[1]					Probability of differences[2]		
Characteristic	EU	EP	LU	LP	SEM	M	P	M × P
Mid lactation								
DM intake, kg/d	21.2	22.0	23.9	23.3	1.61	.042	.911	.372
NDF intake, kg/d	5.3	6.3	5.6	6.0	0.28	.856	.002	.074
Starch intake, kg/d	4.7	4.7	6.9	6.5	0.26	.001	.115	.118
Starch/NDF ratio	0.89	0.74	1.27	1.08	0.03	.001	.001	.335
DMD[3], %	69.4	73.3	68.0	71.6	1.12	.094	.003	.797
NDFD[3], %	47.4	51.0	38.2	41.2	1.85	.001	.053	.943
StarchD[3], %	93.2	97.7	92.0	98.6	0.96	.796	.001	.150
Late lactation								
DM intake, kg/d	18.8	22.8	21.2	21.5	0.95	.431	.033	.019
NDF intake, kg/d	4.9	6.2	4.9	5.4	0.27	.090	.002	.042
Starch intake, kg/d	4.5	4.8	6.0	5.8	0.31	.001	.819	.239
Starch/NDF ratio	0.93	0.79	1.24	1.07	0.03	.001	.001	.707
DMD[3], %	69.1	73.2	69.4	73.4	1.23	.979	.002	.671
NDFD[3], %	51.1	51.2	47.7	43.7	2.50	.010	.181	.196
StarchD[3], %	92.3	98.1	90.1	98.3	0.73	.412	.001	.223

[1] EU = Early Unprocessed; EP = Early Processed; LU = Late Unprocessed; and LP = Late Processed.

[2] M = Maturity main effect (E vs. L); P = Processing main effect (U vs. P); and M × P = Maturity by Processing interaction.

[3] D suffix = digestibility expressed as a percentage of the constituent.